Mr. J. A. Legarra, Chief
Division of Construction & Research

June 20, 1975

Division of Construction & Research

Value Engineering Study - "Mudjacking"

In June of 1973, the Headquarters Value Engineering Branch solicited all District Directors and Headquarters Branch Chiefs, for items or procedures which might warrant Value Engineering investigations.

One of several replies received was a suggestion from Transportation Lab to investigate the mudjacking of sunken pavement slabs. The findings of an investigation of the equipment, procedures and materials used in mudjacking are as follows:

a) Average annual cost Statewide of mudjacking is $500,000+ not including traffic controls, lane closures, and user costs associated with accidents, delays, etc.

b) Twenty-five percent (25%) of areas mudjacked require readjustment every 1 to 5 years.

c) Areas predominantly requiring mudjacking are located at bridge approaches.

d) Effectiveness of current procedures cannot be determined presently by any reasonable means since direct observation of condition below the slab is impossible.

e) Boring procedures and pavement removal for subsurface investigation were considered beyond the scope of this Value Engineering study.

In conclusion, this portion of the Value Engineering study developed no promising solutions to reduce mudjacking expenditures (see Appendix A - Report by L. R. Arnott 12-10-73). Further exploration of the mudjacking problem by J. Evans and Walter White revealed an item with potentially promising results, i.e.,

"A non-destructive testing device, using high resolution radar, capable of looking down through concrete pavement and detecting voids beneath the slab."

Work 6/30/75 DH 7-25

The equipment is now in the experimental stage and offers the greatest potential for solving the mudjacking problem as well as a wide variety of uses for highway and bridge maintenance. At the present time development of this device is directed at methods of calibration for specific tasks and interpretation of output results.

We strongly recommend that all branches of CALTRANS keep abreast of research in this area.

This report closes the Value Engineering effort except as noted on page 6.

Original Signed by
E. D. Spartz

E. D. Spartz, Chief
Value Engineering Branch

Attachment

JSE:sam/s
cc: Travis Smith, Maintenance
W. H. Ames, Transportation Lab
Guy Mancarti, Structures
Jack Cropper, Construction

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J. S. Evans &
W. W. White
Value Engineers

Mudjacking Study

SYNOPSIS

The Value Engineering study on mudjacking was conducted by Bob Arnott with some assistance by Bob Hubbs during the information gathering phase.

Prior to returning to District 02, Arnott prepared the interim report draft attached, Appendix A. The project was then assigned to me for the responsibility of concluding the study. At the time I concurred with the findings and conclusions by Bob; but I asked Frank Baxter if I could look into the application of subsurface detection equipment in regard to mudjacking. He gave his concurrence and permission of assistance by Walter White.

What appears to be needed is a simple economical piece of equipment that can be rapidly propelled over a stretch of highway to detect the location and magnitude of voids under slabs. With these areas accurately defined, the mudjacking effort can be more efficiently defined and resources utilized.

CONTINUED STUDY

The following is a summary of our investigations:

We obtained articles on non-destructive testing techniques through the library, HRIS, and the Geophysics unit at Transportation Lab. The Lab has had previous correspondence with Geophysical Survey Systems, Inc. of North Billerica, Mass., an organization offering themselves as a sophisticated survey service primarily to utility and municipal clients. The service employing their radar equipment and personnel, grids (10 foot intervals) an area such as an intersection to obtain subsurface profiles of underground utility lines. Attempts to obtain costs were not productive.

HIGH RESOLUTION RADAR

Highway Research News, Winter 1973, carried an article on a radar unit that could look down through concrete pavement. The developer was Calspan Corporation in Buffalo, New York. Their equipment, developed for the Army to detect non-metallic mines (plastic), was quite impressive in its stated application to highways.

Though experimental, it had been tested successfully for its designed purpose.

The equipment is a high resolution short pulse portable radar capable of "looking down" through concrete and several feet of soil. Anthony V. Alongi, Staff Scientist at Calspan Corporation, was contacted and he indicated that tests of the instrument show it has the capability to determine pavement thickness, depth of an asphalt overlay of concrete, depth and position of reinforcing steel embedded in concrete and location of voids beneath the pavement. The resolution or accuracy is one eight of an inch to a depth of about 18 inches (see Appendix 'B'). He estimated the experimental model cost at approximately $20,000 but believed that, on a production basis, the price could drop to $15,000.

Calspan offered their services consisting of three days of data gathering, two to three weeks for data analysis and a report on their findings for a cost of $6400. However, Transportation Lab, Office of Structures, and Maintenance representatives felt that the cost was too high an amount for a demonstration of a piece of equipment still somewhat in the development stage, especially in its application to highway engineering. If the equipment could perform as claimed, it was felt the developer should be willing to demonstrate it at his expense.

GENERATE INTEREST

We contacted M. Lastra, FHWA Region #1, Elsmer, New York and developed interest to the point of generating a demonstration of the Calspan equipment on the East Coast. The demonstration was made to representatives of the New York Thruway Authority and FHWA. A report documenting the demonstration was written citing its potential application to highway activities, and a copy forwarded to us, Appendix B. The report supported our feelings that the development had an economical applicaton to the mudjacking operation, as well as having applications in construction, highway maintenance and bridge maintenance areas.

TRANSPORTATION LAB MEETING

A meeting was held at the Transportation Lab to determine if there was enough interest to sponsor such a project. Representatives from Transportation Lab (Concrete, Asphalt, Soils Mechanics, Geology and Research Coordination units) attended. Also attending was Guy Mancarti from Office of Structures Research and Development and Bob Wilson of Office Engineer.

While some of those attending the meeting described disappointments with other subsurface investigating devices and methods now available, the majority seemed to believe the Calspan device shows promise and that such an instrument is also <u>much</u> needed if it can fulfill the claims.

The consensus at the end of the meeting was that New York or some agency closer to Calspan could evaluate it more economically than we; and that we limit our efforts to supporting research by others and to obtaining more performance data from the military who sponsored its development. The general feeling expressed by the group seemed positive toward the idea, but negative toward Caltrans spending the money to try out the equipment.

FURTHER PURSUITS

The National Technical Information Service, Springfield, Virginia, was contacted for information about the military performance with no results. Through Calspan Corporation we contacted Mr. Louis Mittleman, the contract administrator for U.S. Army Mobility Equipment Command, Research and Development, Fort Belvoir, Virginia. He held high praise for the Calspan instrument, because of its very satisfactory performance for military use and the many other applications they found for it. He felt its rather simple design should not be difficult to duplicate or manufacture. He envisioned a cost as low as $10,000 once manufactured for broad use. Mr. Mittleman said that while some aspects of the equipment are security classified, he did not see any problem in using the instrument technology for Civil Applications.

Headquarters Maintenance solicited an opinion regarding the device from District 07 Maintenance, who do the greatest volume of mudjacking in the State.

Value Engineering personnel met with District 07 Maintenance and presented the findings to date. They indicated that the equipment appeared too sophisticated for Maintenance field personnel. Presently, they are satisified with the current mudjacking operation which apparently has been well developed.

Through contacts with FHWA personnel who were interested in the broad application of non-destructive testing we found that several somewhat related electromagnetic research projects were in various stages of study and development. We contacted Stanford Research Institute and Southwest Research Institute (SWRI) for a resume of studies in this category.

The Port Authority of New York and New Jersey has submitted an unsolicited research proposal to the Federal Highway Administration, Office of Research. The proposal, No. 1-75 May 1975, is titled "Radar Evaluation of Concrete" and requests financial support of $30,000 for a field test and evaluation of the downward looking radar developed by Calspan Corporation. We have sent a letter to Mr. C. F. Scheffey, Director of Research, FHWA, Washington, D.C. stating our supporting views in the need for this research.

Dr. Tom Owen of SWRI, San Antonio, Texas is very knowledgeable on the subject. He is involved in a research project for the State of Florida to develop equipment that could detect large voids under the roadbed resulting from subsurface hydraulic erosion. We were able to get Dr. Owen to make a presentation in Sacramento on the State-of-the-art of non-destructive testing technology.

STATE-OF-THE-ART PRESENTATION

The presentation was made here December 10, 1974. Personnel from Transportation Lab (Concrete, Structural Materials, Geology, Pavement and Corrosion units); Structures (Research, Construction, Geology and Maintenance units); Highway Maintenance; Office of Construction, and Office Engineer from Caltrans and three representatives from FHWA attended, twenty-four persons in all. The presentation was highly technical and apparently aimed at proving the theory that it was technically practical to produce the equipment to perform the functions applicable to highways as claimed by the Calspan developers. His pitch seemed to be more toward obtaining a research proposal from Caltrans than a state-of-the-art talk we'd hoped for. In essence, he iterated that at the present time there is no marketed equipment optimized to perform the specific functions required in highway related fields. He also stated that, while there is considerable interest in this area, more development is necessary. In Dr. Owen's opinion the high resolution, short pulse radar is probably the best suited for our application over the other techniques being researched at this time.

SUMMARY

The interim report by Arnott identifies two objectives in the mudjacking function of "restoring rideability":

1. Elevate the sunken slab.

2. Reestablish the base support.

The present procedure poses no problems in obtaining a precise profile grade adjustment. There is, however, a problem in providing a new base support to maintain the adjusted profile. This is evident from the fact that 25% of the work requires readjustment every one to five years. The major factors contributing to the problem are two unknowns.

1) MAGNITUDE OF PROBLEM

We do not know the magnitude of the problem (size and location of void) to start with and once the sunken slab has been restored to grade we are not sure that all of the voids are filled.

2) QUALITY OF SUPPORT MATERIAL

The supporting qualities of the mud are unknown since it is necessary to weaken the material for fluidity in an attempt to fill remaining voids without disturbing the restored slab.

RADAR APPLICATION TO MUDJACKING

By utilizing the radar device mentioned previously a preventative maintenance program could be undertaken. The size and location of voids under the slab could be detected before structure failure occurs. The corrective work could then be performed. A portable radar unit could be used to verify that the voids were filled. Advantages of this system are: 1) The number of holes to be drilled would be reduced to only those necessary to fill the cavity. 2) Hot asphalt would be safer to use for the fill material as the pumping pressure would not need to be as high as required for lifting the slab. 3) The fill material used could be suited to the size, shape and location of the cavity. 4) The supporting qualities of the fill material could be improved as the pumped material would not have to be as fluid as that now used.

CONCLUSION

Non-destructive void detection through high resolution radar technology is not only possible but offers a very good economical potential in a wide variety of applications to highway work. Other areas of use could be:

a. To measure pavement and subbase thickness
b. To determine overlay thickness, i.e., A.C. over concrete
c. To locate subsurface utilities, voids, erosions, boulders, etc.
d. To determine the location of steel in concrete structures
e. To detect and determine the parameters of deleterious materials such as mud balls in concrete pavements or structures
f. For soils investigations before, during and after construction
g. For condition surveys of bridge decks, possibly delamination and steel erosion
h. To locate water cross-overs for landscape projects, i.e., plastic, vitrified clay, soil cement or asbestos transite pipe

An instrument to perform this testing has not been marketed as yet. The development has progressed to several experimental models with a broad range of capabilities. The areas requiring further development are equipment optimization for specific tasks and data interpretation expertise.

RECOMMENDATIONS

Mudjacking is now performed after failure of the structure has occurred. The defined function to "restore rideability" to the sunken slab is performed by procedures adapted over many years. Any improvement to the mudjacking operation should be through resolving the following unknowns:

1. What is the extent of the problem?
   Size and depth of the cavity?

2. Has adequate support been restored after mudjacking?

We believe the key to these unknowns may lie in the radar instruments and applications now being researched. With this technology the unknowns could be resolved and many economies through a preventative maintenance program could accrue.

This generally concludes the study effort by Value Engineering on Mudjacking and no specific changes for cost reduction are offered. However we will:

1. Continue to monitor research activities in the area of non-destructive testing.

2. Maintain liaison with the contacts established under this study:

   --Calspan Corporation, Anthony Alongi.
   --Southwest Research Institute, Dr. Tom Owen and Sid Suhler.
   --New York Thruway Authority, Bob Donnaruma.
   --New York Port Authority, Ted Cantor.
   --Federal Highway Administration, Cliff Pelton, Special Studies Engineer, Arlington, Va.
   --Caltrans personnel that have been involved representing Transportation Lab, Office of Structures and Maintenance.

3. As recommended by Bob Arnott, the Transportation Lab should continue research directed at determining the cause of settlement at bridge ends. However, we do not suggest that a California-sponsored research project to improve the supporting qualities of the mudjacking material be undertaken now. The radar equipment could aid considerably in this effort. Research on slab support material should follow soon after the radar technology is perfected.

J. Evans
Value Engineer

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APPENDIX 'A'

12-20-73
by L. R. Arnott

MUDJACKING INTERIM REPORT

This Value Engineering study has progressed into analysis of the speculation phase and no promising alternatives have developed. There is not enough information available to determine the appropriateness of the present procedures or the cause of ineffectual treatments.

This is largely because there is no opportunity for direct observation or measurement without investigative borings or windows beneath the pavement. Experienced mudjack personnel operate on visualization and speculation with little or no evidence to reinforce their assumptions.

BACKGROUNDS

The mudjacking function "restore rideability" is divided into two objectives. The first is to elevate the sunken slabs and the second is to reestablish base support.

The present procedure seems well adapted for the precise profile grade adjustment. This can be continually observed and controlled. Providing an adequate base support to maintain this adjustment is where we are working in the dark. We have no positive method to assure that the resultant voids have been adequately filled.

The Statewide yearly activity cost for mudjacking is $550,000. In addition to this direct charge is the cost of traffic control and a users cost in accidents and service loss resulting from the lane closure.

Approximately 3/4 of the locations treated are satisfactory for about 10 years. The other 1/4 require readjustment every one to five years and this is where most of the demand exists. The latter 1/4 are primarily at bridge approach slabs where profile smoothness is most critical.

It appears that numerous bridges constructed on the Interstate program have inherent approach fill problems. As these settlements begin to appear we can anticipate an increased demand for mudjacking unless the treatment can be made more permanent.

OPERATION

In the approach slab adjustment observed by Value Engineering the pumping was done in the a.m. and drilling at the next location done in the afternoon. This provided maximum cure time before traffic loads were imposed on the new grout.

Holes were drilled about two feet deep to get grout introduced below the cement treated base. It is preferable to have the stronger cement treated base under the pavement and the weaker grout below the cement treated base. The grout, however, enters whichever layer it can separate the easiest and begins it's lifting pressure.

A stiff grout is used to raise the slab which is a delicate operation requiring precise control to keep the slab from raising too high or raising the adjacent slabs or shoulder.

After the slab is raised, more water is added to the grout to promote flow into resultant voids without further raising the slab. Once raised and free from interlocked joints the slab can be raised with less than one pound per square inch.

Reestablishing support is the area where the method and materials do not seem compatible with the intended function. Holes used to raise slab are lined with partially set mud that resists introduction of the filler material. The minimal strength grout is further weakened by additional water which increases the water-cement ratio, the shrinkage and the initial set time. All three are detrimental to the only function of the filler material which is to permanently maintain the slab position.

CONCLUSION

An apparent solution is changing to a filler material that is more fluid, faster setting, more dense and stronger. The probable cost of added equipment, training and other implementation considerations, however, is difficult to justify without some evidence that this is the cause of treatment failures.

Continuous settlement of approach slabs may be caused or contributed to by numerous other actions. Subsidence, fill settlement, migration of base or fill material and movement of abutment or wing walls are all possibilities that no filler material would correct.

Introducing another filler material under all sunken pavement would be only continuing the "hit and miss" results we've been experiencing. An investigative approach incorporated with the present operation would provide some basis for conclusions that are now almost completely speculative.

The physical testing and measurement of such an investigation appear to be beyond the scope and capacity of Value Engineering personnel.

RECOMMENDATION

The Transportation Laboratory commence a research project to:

1) Determine the cause of continual settlement at bridge ends and
2) Measure the physical properties of presently used materials to improve their performance life.

The scope of the study should be envisioned by and approximate cost of about 10% of the yearly mudjacking cost or $75,000.

District 07 with the most varied and progressive experience should collaborate in selecting control sites and monitoring costs and performance.

The prime objective of this research project would be to improve the permanence of the restoration. In the course of this pursuit also:

1) Identify cause for repeated mudjack adjustments.
2) Accumulate costs at sample repetitive locations.
3) Measure effectiveness of present procedure and materials.
4) Examine plausible alternatives.

To be comparable to the presently used filler support material any substitutes considered should:

1) Be capable of introduction with no more traffic disruption than is presently used.
2) Have initial fluidity to flow into small voids without pressures that would raise the slabs.
3) Set up to resist deformation from traffic loads within 2-4 hours.
4) Precisely fill and maintain the void volume with minimum shrink or swell.
5) Have ultimate compressive strength of cement treated base. (500 to 750 psi)
6) Resist deterioration from long term soaking and high velocity water erosion.

Other desirable properties would be:

1) Controlability for precise slab raising so crews still have only one material to handle.
2) Non-compressible - so change in pressure will not result in significant volume change in either the fluid or solid state.
3) A mixture pot life of 2-3 hours.
4) That existing equipment could be utilized in its operation.
5) An impermeability that could serve as a subsealant.

MUDJACKING MATERIAL

The grout material presently used is a mixture of natural fines or talc, diatomaceous earth, plaster of paris, cement and water. The general recommended proportions are in the work standards.

Cost of a new automatic pump truck is $55,000.
Cost of the ingredients is about $12 to $16/CY.
The pumped in-place cost is about $145/CY.

The material is premixed far in advance of introduction of water and pumping. The clodding-up of material indicates that the moisture in the aggregate causes some prehydration of the cement hours before pumping takes place.

Following are some questions concerning the appropriateness of the grout and its use.

Is grout mixture designed to facilitate the operation and equipment without regard to function accomplishment? Since fine clayey aggregates aren't normally compatible with cement for concrete strength.

Is this clayey aggregate used only because it is cheap ($5/CY) or because better material can't be pumped?

Could an additive substitute the lubricative function of the clay and excessive water? The 50 to 100 gal/CY of water occupy 6 to 12 cubic feet of the 27 cf/CY and probably shrinks considerably in curing.

How much available strength is lost by premixing and pre-hydration of cement?

Could revised procedure insure that cavities are filled with grout?

Does material set-up sufficiently to resist deformation and inigration from traffic loads?

Does this grout have enough compressive strength or durability to expect even thin layers to provide the base support of cement treated base? Components of this grout have characteristics similar to materials that are rejected as "unsuitable material" for use within 2.5 feet of grade by construction practices.

Might large volumes of this grout actually be the most unstable portion of an approach fill?

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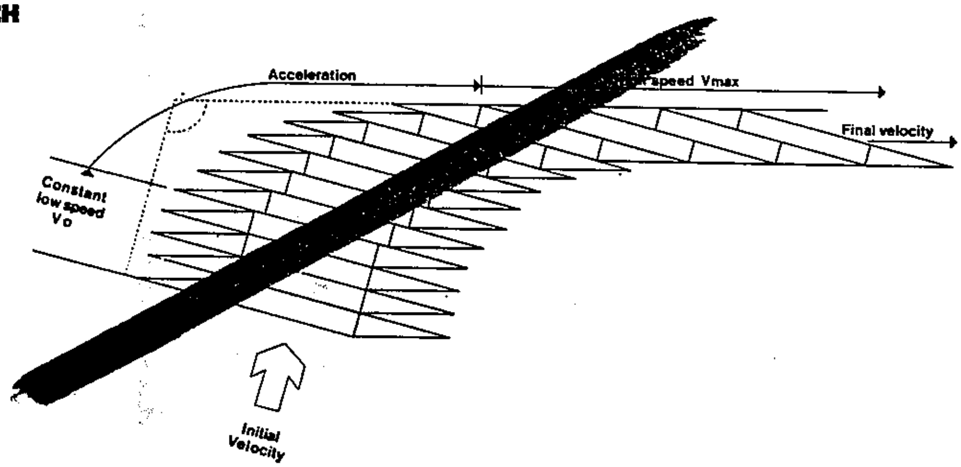
APPENDIX 'B'

NUMBER 53
WINTER 1973

HIGHWAY RESEARCH NEWS

HIGHWAY RESEARCH BOARD

National Research Council
National Academy of Sciences
National Academy of Engineering



under the influence of the guide rails. In this zone the passenger standing o[redacted] the platforms follows a carefully controlled, curved path designed to limit [redacted] acceleration to a comfortable level. The combination of forward and s[redacted]ys movement produces an acceleration at the end of which the platforms[redacted]ge smoothly into the main high-speed transport zone, where they ar[redacted]traveling at up to five times their entry speed. In the high-speed zo[redacted]ich is straight and which can be of any desired length to suit the [redacted]ar application, there is at this stage no sliding of one platform rel[redacted]o the next. Sliding of the platforms takes place again as they ent[redacted]curved deceleration zone and there is a short straight constant spe[redacted]e before the platforms pass through the exit combplate. The direction [redacted] system is reversible.

The unit is fitted with a conventional balus[redacted] on both sides and this is curved at entry and exit to follow the line [redacted]edge of the platforms. A moving rubber handrail of conventional app[redacted]e is fitted on top of the balustrade. This handrail is divided into a serie[redacted]nstant-speed zones that approximately match the mean speed of t[redacted]tforms in that zone.

Passengers entering the sy[redacted]hold the handrail, which moves at exactly the same speed as the platf[redacted]on which they stand. As they begin to accelerate they can continue t[redacted] the handrail in the same position, but their hand begins to move back [redacted]they are then moving slightly faster than the handrail. Before a pa[redacted]r's arm position has become uncomfortable, he has reached the nex[redacted]ion of the handrail and can readily transfer to it. In the high-speed t[redacted]ort zone the handrail moves at exactly the same speed as the platforms[redacted]

Dri[redacted]provided by 28 variable-speed electric motors, which are reversible[redacted] drives are automatically synchronized.

[redacted]ther details of the system can be obtained from the Manager, Speedaway [redacted]tems, Dunlop Limited, Transportation Systems Division, Denbridge In[redacted]ustrial Estate, Oxford Road, Uxbridge, Middlesex, England.

Pavement Thickness Measured, Voids Detected By Downward-Looking Radar in New York Test

A high-resolution radar has recently been employed by the Calspan Corporation of Buffalo, New York, to look through a pavement section of the New

York State Thruway. The radar was employed at a test site on a section of Thruway recently closed for repairs. Anthony V. Alongi, Program Manager responsible for the development of the radar, said that the test results indicate the instrument has the capability to determine pavement thickness of the surface blacktop and thickness of the subsurface concrete and has located the position and depth of reinforcing rods imbedded in the concrete. The instrument has also located voids beneath the pavement.

The system employed for these tests consists of a low-power, short-pulse, high-resolution radar developed originally for the U.S. Army. Calspan's civilian version of the equipment would emit, each second, more than one million pulses, each about one billionth of a second long. A battery-powered portable version of this system weighs less than 20 pounds and employs a constant-flare-angle variable-width open-horn antenna developed especially

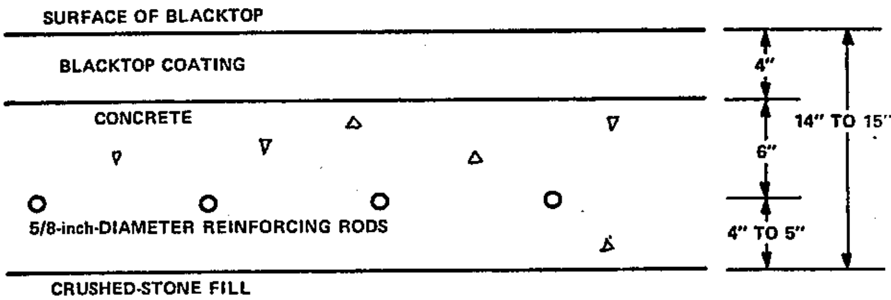
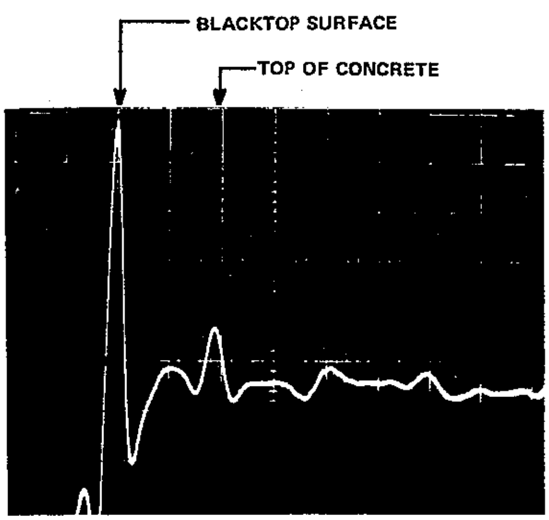


Figure 1. Cross section of bridge approach, north side, northbound bridge, Wehrle Drive and New York State Thruway, near exit 50.



VERTICAL SENSITIVITY: 200 mV/cm
HORIZONTAL AXIS: 1 ns/cm

Figure 2. Data taken on bridge approach, northside, northbound bridge, Wehrle Drive and Thruway. Blacktop coating 4 in. thick on top of 10 in. concrete, with $\frac{5}{8}$ in. reinforcing rods placed approximately at center of concrete.

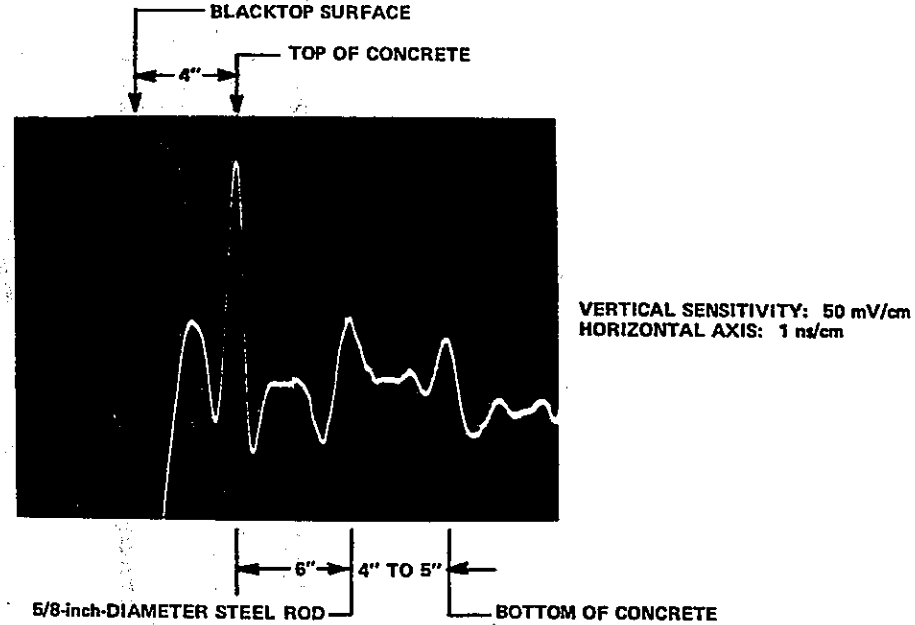


Figure 3. Data taken on bridge approach, northside, northbound bridge, Wehrle Drive and Thruway. Blacktop coating 4 in. thick on top of 10 in. concrete, with 5/8 in. reinforcing rods placed approximately at center of concrete.

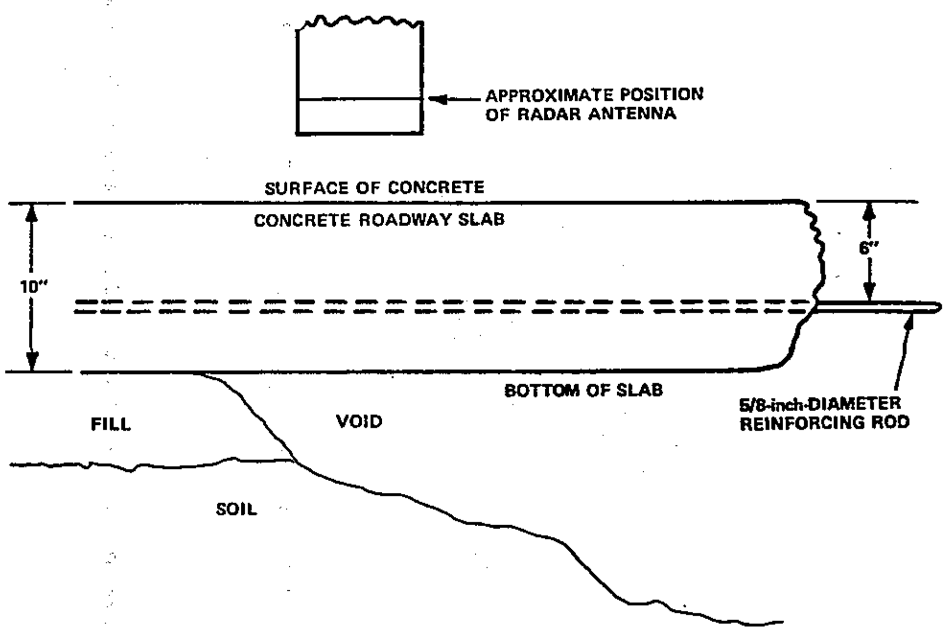


Figure 4. Void under concrete roadway slab.

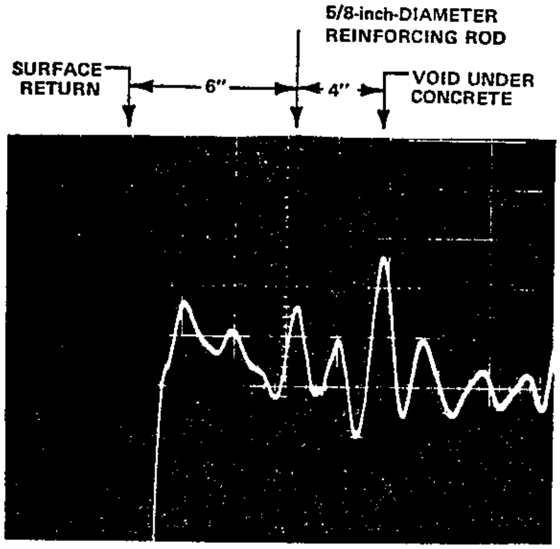


Figure 5. Radar return of void under concrete roadway slab.

for this radar. The radar is normally held approximately ½ foot above the ground and employs an oscilloscope display that is stabilized by means of a soil locking circuit that makes the system insensitive to antenna height variations. Pavement thickness measurements are made possible by the fact that the various layers of highway substructure represent electrical discontinuities to the radio frequencies employed by the radar. These discontinuities give rise to radar reflections or echoes that are then presented on an oscilloscope display. It is believed that pavement thickness measurements may be made to within ⅛ inch.

Experimental highway pavement results are illustrated in the accompanying figures. Figure 1 is a sketch of the cross section of the New York State Thruway test site. The radar oscilloscope display showing the response of the highway pavement is shown in Figure 2. The first and strongest radar response occurs from the surface of the blacktop followed by the response arising from the interface between the blacktop and concrete surface. The amplitude of the radar response is represented by the vertical displacement on the radar oscilloscope while the subsurface depth is represented as a displacement along the horizontal axis of the radar oscilloscope. Figure 3 shows the radar response at the same test site with the amplitude sensitivity of the oscilloscope increased by a factor of four. The radar response can be clearly seen arising from the blacktop-concrete interface and from the tie rods imbedded in the concrete and from the bottom of the concrete. It was observed during these tests that some of the rods varied in depth on the order of 1 inch. Thickness estimates to within an eighth of an inch may be possible with this system. Figure 4 is a sketch of a second New York State Thruway test site at a ramp approach to a bridge overpass. The radar was positioned at a location where the soil is just beginning to separate from the concrete roadway slab. The air void is clearly detected, as shown in Figure 5.

Calspan plans to make this equipment available shortly for civilian use. Further information may be obtained from Anthony V. Alongi of the Calspan Corporation, P.O. Box 235, Buffalo, New York 14221.

Calspan News

Calspan

Formerly Cornell Aeronautical Laboratory, Inc

Information on Developments at Calspan Corporation P.O. Box 235 Buffalo, New York 14221

An Air Force NT-33A flown by C span test pilot G. Warren Hall hooks with a KA3R Navy tanker for refue . The hookup was the first in-fligh e-fueling of an aircraft under "f y-wire" control. In such a system, ch is common in the space progra the pilot's movement of the trols creates electrical signals. The ravel along wires to hydraulic val which move the control surfaces. a conventional aircraft, the pi s stick, rudder pedals and other rols are connected mechanically n the aircraft's aerodynamic contr urfaces.

The tests were unde en for the Air Force.

Swonger Ap inted To Product e Post

Claron W. Swo r has been appointed product manager of a new organizatio unit devoted to product develo nt programs in Image Data Sys s.

Mr. Swong becomes the first product line ager in the company's 27-ye story. His appointment is des d to place stronger emphasis several of Calspan's commercia oduct-oriented efforts and to m growth objectives for the futur

Initia Calspan Image Data System ll concentrate on development manufacturing and marketing systems utilizing fingerprint ntification technology.

M Swonger had been head of Cal 's Computer Systems De pa ent since 1970 and led the de ve ment of an automatic finger reader for the Federal Bureau nvestigation. He was succeeded head of Computer Systems by les W. Hall.

Radar Developed For 'Looking Down'

A portable radar capable of "looking down" through concrete and several feet of soil has been developed by Calspan Corporation for various uses, from detecting buried objects to monitoring the subsurface conditions of highways.

The penetrating radar was developed in association with the Mine Detection Division, Countermine Counter Intrusion Department, of the U. S. Army Mobility Equipment Research & Development Center at Ft. Belvoir, Va.

Anthony V. Alongi, staff scientist from the company's Electronics Department, said the system can be used to locate and signal the presence of such buried objects as plastic mines, human bodies, and underground conduits.

"The nature of the radar return distinguishes these substances from each other and from such natural subsurface formations as rocks and boulders," Mr. Alongi reported.

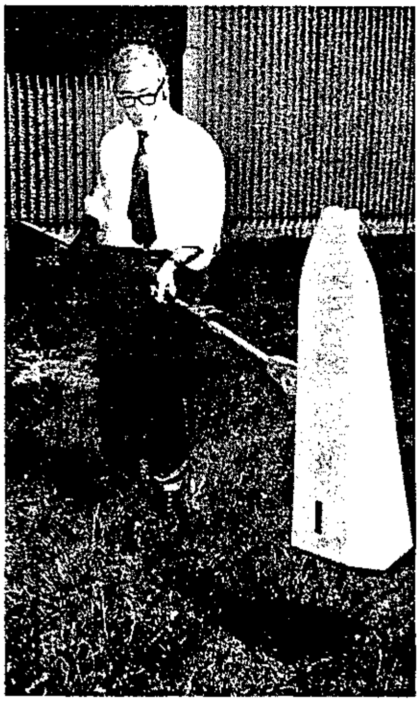
"It measures their size and depth-below-the-surface within a few inches, thus telling precisely where and how to dig."

An Army announcement said the experimental equipment supplied by Calspan "has demonstrated excellent potential in the field tests." The Army has wanted such equipment since the development of plastic mines, which contain no metal and therefore cannot be spotted by conventional mine-detectors. Such mines, which are inexpensive to manufacture, caused many of the U. S. casualities in Southeast Asia.

One major civilian use will be to map the exact location and depth of underground conduits, sewers and water lines, whether encased in metal or plastic, and as small as 2 inches in diameter.

The equipment was used recently in the Buffalo area, for example, to measure the extent of deterioration in the cap of a concrete column supporting an overpass on the New York State Thruway. Deterioration proved to be very severe.

Calspan also developed, in association with the Army, a one-man version of the radar system weighing less than 20 pounds (see photo).



Staff Scientist Anthony V. Alongi displays a one-man portable version of the radar system as it "looks down" into the soil.

news Calspan
Calspan Corporation P.O. Box 235 Buffalo, New York 14221 (Formerly Cornell Aeronautical Laboratory, Inc.)

For further information call:
(716) 632-7500
Anthony V. Alongi, Ext ~~433~~ 358

FOR IMMEDIATE RELEASE

BUFFALO, NY --- A portable radar capable of "looking down" through concrete and several feet of soil has been developed here by Calspan Corporation for various uses, from detecting buried objects to monitoring the subsurface conditions of highways.

The penetrating radar was developed in association with the Mine Detection Division, Countermine Counter Intrusion Department, of the U. S. Army Mobility Equipment Research & Development Center at Ft. Belvoir, Va.

Anthony V. Alongi, staff scientist from the company's Electronics Department, said the system can be used to locate and signal the presence of such buried objects as plastic mines, human bodies, and underground conduits.

RW:49/73

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"The nature of the radar return distinguishes these substances from each other and from such natural subsurface formations as rocks and boulders," Mr. Alongi reported.

"It measures their size and depth-below-the-surface within a few inches, thus telling precisely where and how to dig."

An Army announcement said the experimental equipment supplied by Calspan "has demonstrated excellent potential in field tests." The Army has wanted such equipment since the development of plastic mines, which contain no metal and therefore cannot be spotted by conventional mine-detectors. Such mines, which are inexpensive to manufacture, caused many of the U. S. casualities in Southeast Asia.

"Calspan is utilizing Army equipment to investigate the feasibility of applying this radar technique to a number of difficult and very important civilian functions," pointed out Mr. Alongi, manager of the company's Radar Mine Detection Program.

"One major use will be to map the exact location and depth of underground conduits, sewers and water lines, whether encased in metal or plastic, and as small as 2 inches in diameter.

"This is particularly valuable in reducing digging at busy street intersections, where the lines may have been buried at varied times over a period of many years, and not always in the locations where the old city maps say they were supposed to go.

"Concrete is, in effect, transparent for the radar. We have traced plastic pipes through and behind concrete walls. Looking down through a concrete highway, you can pick up the tie rods beneath. Also any voids in the subsurface caused by the underside of the concrete leaching away or hidden water undermining part of the roadway's foundation.

- more -

Mr. Alongi said a version of the radar with multiple antenna horns, carried on a vehicle, could easily be built to monitor the subsurface condition of major highways. "Cruising at 60 mph, it could be used to guide routine maintenance, or survey entire highway systems for hidden weakened spots in areas where major flooding has occurred."

Calspan has also developed, in association with the U. S. Army, a one-man version of the radar system weighing less than 20 pounds. Straps over the operator's shoulders support a 10-foot-long horizontal boom. The antenna horn is mounted vertically at the end of the front half of the boom. Batteries and transmitter are in a balancing box at the back end of the boom. The equipment can be set to produce a video signal--visible on the screen of a small oscilloscope on the operator's chest--or an audio signal heard in his headphones.

Detection is made possible by the fact that every discontinuity in the soil--even a change from one density to another, or wet to dry--is accompanied by a change in electrical properties. As the radar signal penetrates the soil, part of its energy is "bounced back" in telltale fashion from each such change. Characteristics of the returned signal relate to the nature of the surface which reflected it.

- more -

Calspan's civilian version of the equipment would emit, each second, more than 1 million pulses, each about 1 billionth of a second long. The antenna developed by Calspan is a constant-flare-angle variable-width open horn. The system employs a soil lock circuit, which presents a stabilized display despite antenna height variations.

"Although military versions are intended primarily for objects buried no more than a foot or two, we can make tradeoffs--in the very precise resolution we now have, for example--which will permit penetration to many feet for civilian projects," Mr. Alongi said.

Among these may be the location of bodies buried in soil, a severe problem in law enforcement for which no satisfactory technology has existed. Current methods include probing the soil with rods and digging up what appear to be recently-disturbed areas--an uncertain and time-consuming process.

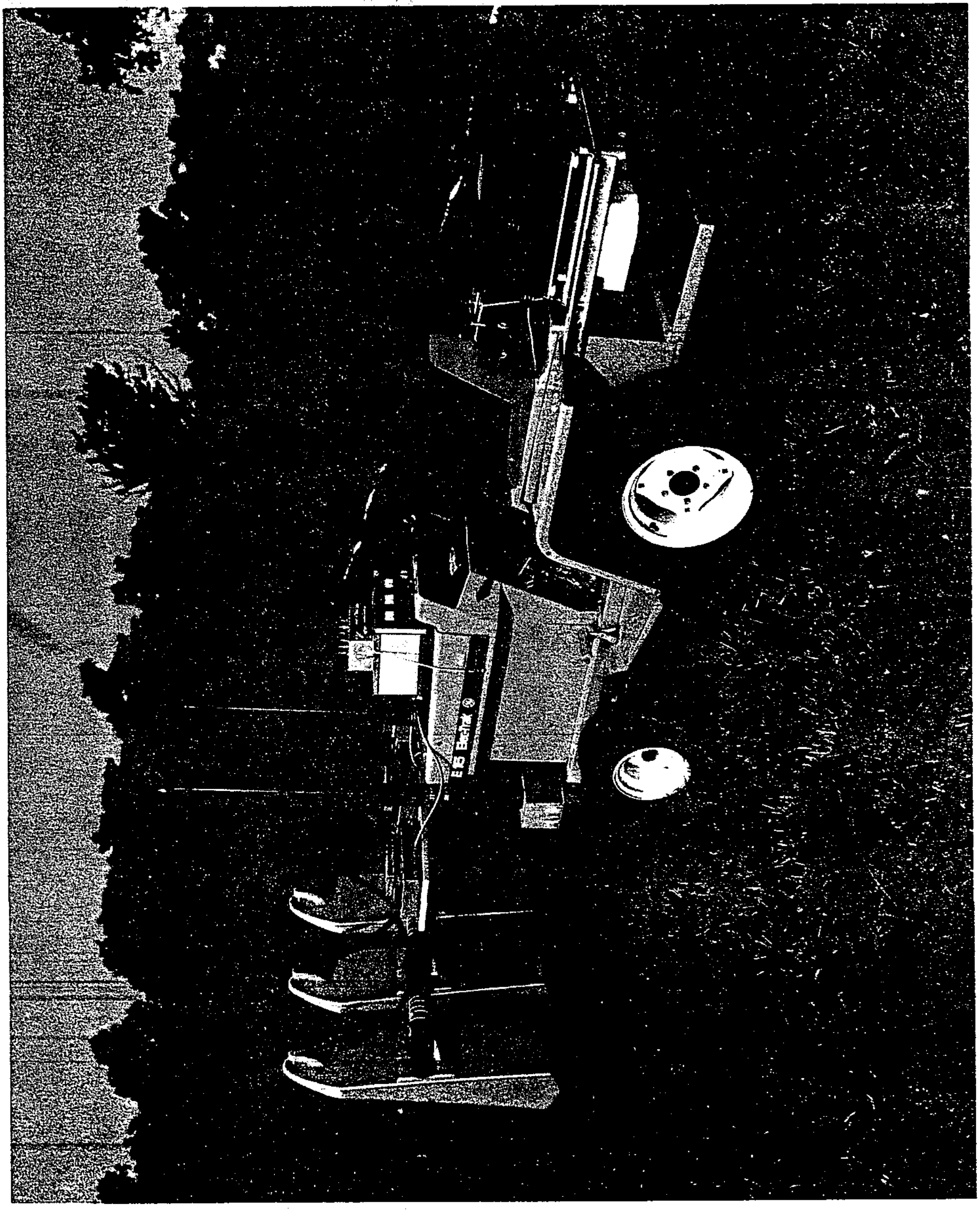
In a recent test, Mr. Alongi reported, the body of a 50-pound collie dog was buried 10 inches deep in sandy loam. The radar signals established the exact positions of his head, chest cavity, rear legs, and tail.

Ways are under consideration for making body-finding equipment available to law-enforcement agencies, Mr. Alongi said.

This radar program is another example of civilian spinoff from a Research and Development Program conducted for the Department of the Army. Calspan, formerly Cornell Aeronautical Laboratory, is an independent engineering organization conducting research and development for government agencies and industry.

- more -

Man Portable Version


Elec-Trak

A SHORT-PULSE HIGH-RESOLUTION RADAR FOR CADAVER DETECTION

By

Anthony V. Alongi
Calspan Corporation
(Formerly Cornell Aeronautical Laboratory, Inc.)
Buffalo, New York 14221

Summary. This paper describes the design investigation of a short-pulse high-resolution radar for detecting nonmetallic subsurface objects and its application to a severe problem in the field of law enforcement: the finding of bodies buried in soil.

There are available numerous useful subsurface metal detectors (for both ferrous and nonferrous objects); however, these are generally incapable of satisfying present needs, which have spread to include objects that are non-metallic in nature, both organic and inorganic. The system described herein has been under development for several years and has been designed to fill this need. Its application to the area of law enforcement in the quick and efficient detection of subsurface, nonmetallic objects, including buried bodies, is discussed.

Subsurface object detection by a high-resolution radar is accomplished primarily by transmitting a very short pulse, receiving its (much weaker) reflection from the target object, and presenting information on the time delay and change of pulse shape between the original and the reflected pulse to a human observer or to suitable automatic recognition circuitry. The transmitted signal must have a sufficiently large bandwidth to permit separation in range (i.e., time) of the very strong soil surface return from the much weaker subsurface object return. To design a useful radar system, it is necessary to determine the best compromise between the operating band of frequencies, soil attenuation and dispersion, and realizable wideband hardware components.

We have successfully designed, fabricated and tested several systems against a variety of buried "targets." Detection and identification of these objects, including the body of a dog, have occurred at depths ranging from one foot of cover in heavy clay to several feet in dry sand. Experimental data demonstrating these observations are presented in this paper.

The research and development on the high-resolution, short-pulse radar has been conducted for the U. S. Army Mobility Equipment Command, Fort Belvoir, Virginia, under Contract No. DAAK02-69-C-0149.

Introduction

This paper considers one problem that law enforcement agencies occasionally face: locating human cadavers (usually victims of a criminal act) buried in shallow graves. Conventional techniques such as probe and dig may be quite laborious and time consuming and frequently require the invasion of private property. Offered for consideration herein is the use of a lightweight high-resolution radar designed to probe the soil subsurface electromagnetically and to detect buried cadavers by a relatively simple visual display which does not require the disturbance of the earth. A practical electromagnetic tool for subsurface probing must be readily man-portable and must present its information in a simple, easily interpretable form. We have been engaged for several years in the development and evaluation of tools of this type and believe that the equipment we have developed is easily adaptable to law enforcement needs.

A buried object, metallic or nonmetallic, organic or inorganic, usually represents a discontinuity in the electrical properties of the subsoil. This discontinuity of the relative permittivity gives rise to a reflection of illuminating RF energy. The soil subsurface will also give rise to a (usually much stronger) reflection of the illuminating energy. A high-resolution radar, one that can resolve targets spaced a few inches apart, may then resolve a shallow buried target from the surface return. Deeper buried targets will give rise to signals better separated in time from the surface return; however, they will suffer from greater signal attenuation as a function of soil conditions. Signal attenuation may be reduced by employing lower frequencies; high resolution, however, dictates the use of a wide bandwidth of frequencies. The problem of buried object detection with a high-resolution radar is then primarily one of transmitting a signal of sufficiently large bandwidth that will permit separation in range of the very strong soil surface return from the much weaker subsurface object return. To accomplish this objective, it was necessary to determine the best compromise between the operating band of frequencies, soil attenuation and dispersion and realizable wideband radar hardware. We have examined both the direct short-pulse and the wideband FM/CW methods. We have previously shown both methods to be essentially equivalent mathematically; our investigation was directed toward assessing practical differences of instrumentation, economics, size and weight.

Radar Design Investigations

To establish system design requirements for the high-resolution radar system, it was necessary to determine the effects of radar components, soil and target on the signal to be detected. A computer analysis was performed by obtaining the Fourier transforms (both amplitude and phase) of the transmitted pulse, the air-soil interface, the soil subsurface, the target and the radar receiver and antennas. These were combined in a cascade fashion and employed in parametric computer studies to determine a desirable range of design parameters. The computer results indicated that high resolution is a valid approach in separating the soil surface from the subsurface target return, provided great care is taken in minimizing the unwanted range sidelobes which plague any high-resolution system. By parametrically varying the pulse bandwidths, it was possible to determine the minimum required bandwidth that will still provide range separation between the surface and subsurface target returns. This consideration is important in system design, since octave bandwidth components having linear phase and amplitude response are within the state of the art, while multiple-octave components generally are not. For the pulse system, the transmitter waveform is approximately a single cycle of 1-GHz energy (1-nanosecond duration) with a pulse repetition frequency greater than 1 MHz. For the FM/CW system, a 0.5- to 2.0-GHz RF sweep source was also developed. Our design investigations indicated that pulsed systems can be made more compact in size and weight than the FM/CW in present-day state of the art and are thus better suited for lightweight, man-portable systems. The data output is stable and more easily interpreted by the average operator than that of the FM/CW; therefore, developmental efforts were concentrated in this direction.

We have designed and evaluated several forms of wideband nondispersive antennas in this radar development. These include an arc sine exponential open-sided horn, a multifilar spiral, and a constant-flare-angle variable-width open horn. The latter type was considered the most suitable for use as part of a short-pulse high-resolution radar and is the one presently in use.

A generalized system description of a short-pulse system is presented in Figure 1. Figure 2 is a sampling oscillograph recording of the short pulse (approximately one nanosecond long and consisting of one cycle of a sinusoidal signal) which is transmitted to provide the high range resolution required for this system. Reflections from buried targets illuminated by the transmitter are received and detected using a sampling technique. The sampled output is displayed and provides an A-scope presentation--signal amplitude as ordinate against time as abscissa--of the actual signal waveform received over a short time (or range) interval. The time interval displayed is approximately 10 nanoseconds; individual targets in this range are visually detected from the display presentation. In free space (open air), this 10-nanosecond interval corresponds to approximately 60 inches; in subsurface media, the same 10 nanoseconds represent a distance ranging from 30 inches for dry sand ($\epsilon_r \approx 4$) to approximately 13 inches for very wet soil ($\epsilon_r \approx 20$).

An early version of a short pulse radar system appears in Figure 3. This system weighs approximately 30 pounds and consists of three main subassemblies: (1) two antennas, (2) display, transmitter and receiver module, and (3) battery pack and associated control electronics module. The use of separate receiving and transmitting antennas is called "bistatic" in radar terminology; if a single antenna is used for both purposes, the radar is called a "monostatic" radar (Figure 4). A monostatic man-portable high-resolution radar is shown in operation in Figure 5. Both systems employ a soil lock circuit, which presents a stabilized display despite antenna height variations resulting from operator motion. As many as eight hours of operation are possible before recharging of the battery pack becomes necessary.

Experimental Results Derived from Buried Objects

Metallic Flat-Plate Tests

This subsection presents experimental results derived with the bistatic and monostatic short-pulse radars. Since both systems have been assembled with almost identical electrical performance characteristics, results shown are applicable to either system. The first series of photographs depict the radar response obtained from a six-inch-square flat metallic plate buried at depths of two, four, six and eight inches in clay soil of approximately 4 percent moisture content (Figures 6 through 9). These measurements were performed with the early bistatic radar in a soil of known constituency on Calspan property. The faint vertical pulse located on the 2-cm line from the left edge of the graticule is the soil return, and the signal return from the buried metallic plate appears displaced to the right of the surface return. The time displacement increases for increased plate depth. In all photographs, the vertical scale is 25 mV/cm and the horizontal scale is 1 ns/cm. Table I presents the radar-measured time delay in nanoseconds as a function of plate depth and the calculated time delay based on knowledge of the relative dielectric constant for clay ($\epsilon_r = 2.8$) at 4 percent moisture. The velocity in the soil is given by:

$$V_s = c/\sqrt{\epsilon_r} = 0.178 \text{ meters/nanosecond}$$

where c = velocity of light in meters/second; thus, the time delay is given by

$$t = 2d\left(\frac{1}{V_s}\right)$$

where d = the depth in meters. It can be appreciated that a slight variation in ϵ_r would shift the values correspondingly.

The measured values of time delays are visually determined by noting the position of the positive peak value of the signal return from the buried plate and measuring the distance to the center of the positive peak signal representing the surface return (located 1 cm from the left edge of the graticule). Note that the width of the oscilloscope trace is on the order of one-tenth nanosecond. With this limit to reading accuracy, there is very close agreement between calculated and measured time delays.

Styrofoam Block Test

The previous test demonstrated the response of the radar against buried metallic targets. Figure 10 shows the radar response for a buried styrofoam block, which was 9" x 12" x 6" and was buried 7 inches deep, with the upper face horizontal. This response illustrates the capability of the radar to detect holes in the ground. Styrofoam, for all practical purposes, approximates the dielectric constant of air. This type of response would be encountered in buried cadavers and would arise from regions corresponding to the chest cavity.

Cadaver Tests

The body of a Collie dog, ~ 30 inches long, 7 inches thick and weighing ~50 pounds, was obtained shortly after his death. This specimen would approximate a rather small human cadaver and would therefore represent the more difficult types of targets to test. The dog was buried ten inches deep in sandy loam at the Calspan Test Lane Facility. The signals obtained from this target are generally the same level as those obtained from the previous targets. Figure 11 shows the position in which the subject was buried prior to being covered with 10 inches of soil. The test lane stations referred to in Figure 11 are the distances in feet and inches along the test lane in the direction of antenna travel.

Figure 12 is the radar response of the soil alone before burying the dog. Note that the soil surface return occurs on the 1-cm graticule mark and is approximately 800 mV peak to peak. Figure 13 shows the radar response of the dog. Note that the response of the dog occurs between the 5th and 6th cm graticule marks. The signal amplitude is greater than 100 mV peak to peak. The antenna of the monostatic radar is located over the chest cavity of the dead dog. Figure 14 shows the radar response when the antenna is located at the 25-foot 9-inch station, which corresponds to the edge of the hole and the dog's head. The soil surface return still occurs on the 1-cm graticule mark; the effects of the hole show up on the left half of the radar display and the response from the dog's head and neck show up on the center portion and right side of the radar display. The chest cavity in Figure 15 shows a very strong return occurring between the 5th and 6th cm of the radar display. This type of response is characteristic of the return from most of the dog's body. Figure 16 was obtained with the antenna located over the rear half of the dog's body. A strong radar signal return similar to that obtained from the front half of the dog's body is obtained. Figure 17 is the return obtained from the 28-foot 3-inch station. This response is obtained primarily from the dog's rear legs and tail. The edge of the hole is beginning to show in the radar display. Figure 18, taken at the 29-foot 3-inch station, shows the effects of the edge of the hole. Moving the radar further down the test lane would give results of the soil return alone and identical to that obtained in Figure 12.

These experiments demonstrate that a man-portable high-resolution radar may be employed as a practical means of detecting buried objects. The holes made by disturbing the natural soil are also detected, even through they have been filled and covered with an appreciable amount of soil fill. Animal bodies or cadavers may be easily detected. By scanning the radar antenna laterally and longitudinally and noting the corresponding signal response, a fair estimate may be made of the size of the burial cavity. Detections may be made by observation of the radar response on a visual display (A-scope), with an operator having only a short period of indoctrination.

Acknowledgement

The author is indebted to Mr. R. V. Gallagher for providing the experimental data contained in this report. He also wishes to thank Messrs. Robert E. Kell and Carmen J. Tona for their initial suggestions for the buried cadaver detection application, which arose from discussions with Mr. Alan N. Rapsey of Scotland Yard, and for their interest and encouragement in preparing this paper. The design and development of the radar equipment discussed herein has been conducted for the U. S. Army Mobility Equipment Command under Contract No. DAAK02-69-C-0149.

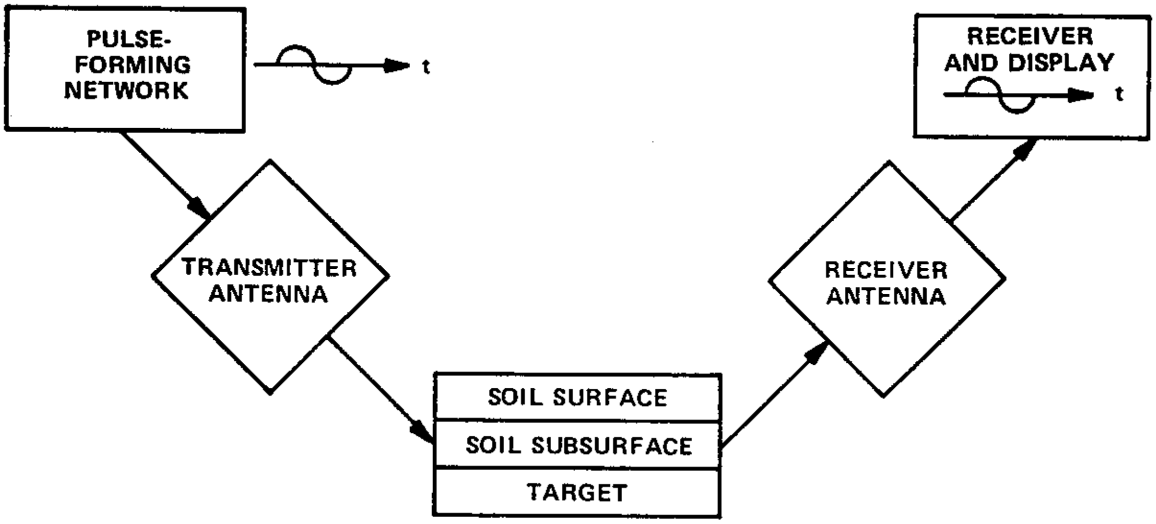


Figure 1 SYSTEM DESCRIPTION

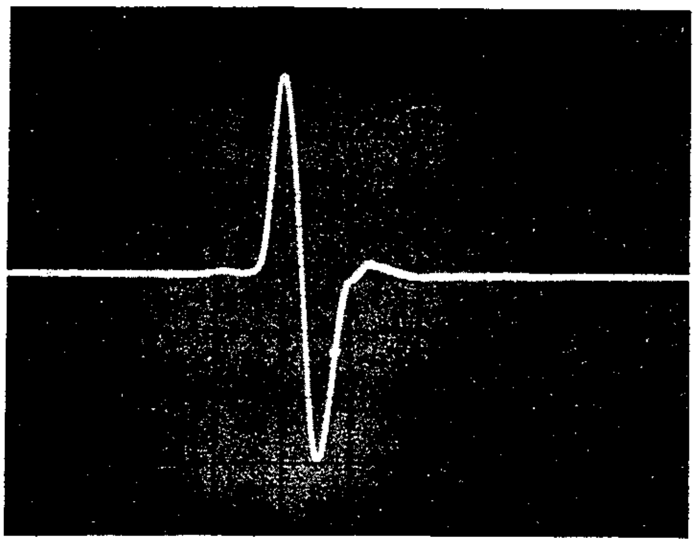


Figure 2 TRANSMITTED WAVEFORM OF THE SHORT-PULSE RADAR SYSTEM (HORIZONTAL SCALE: 1 ns/cm)

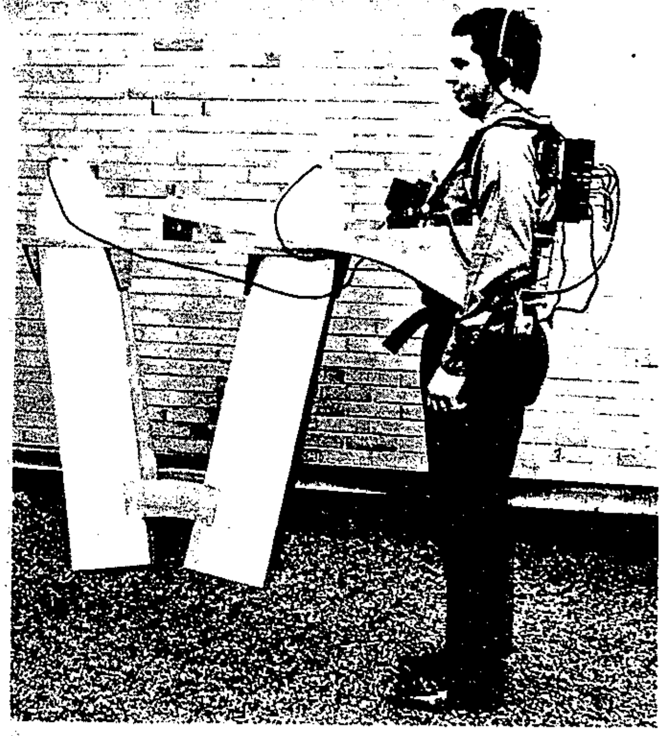


Figure 3 EXPERIMENTAL BISTATIC SHORT-PULSE RADAR

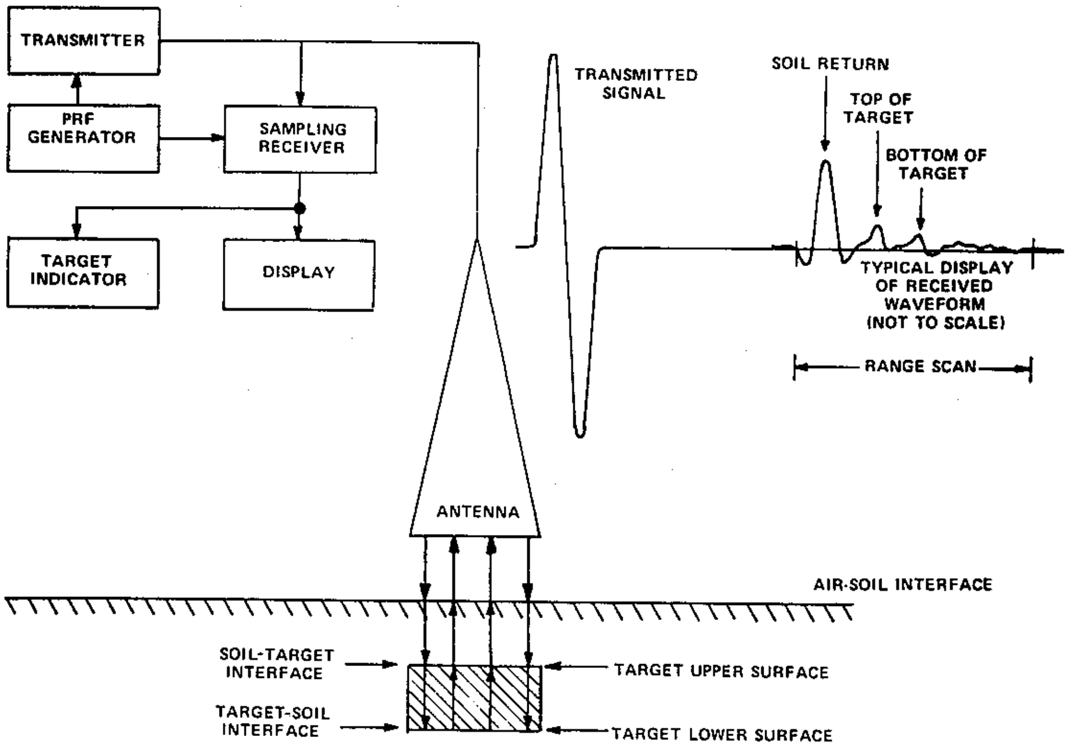


Figure 4 BASIC SHORT PULSE MONOSTATIC RADAR OPERATION

Figure 5 EXPERIMENTAL MONOSTATIC SHORT-PULSE RADAR

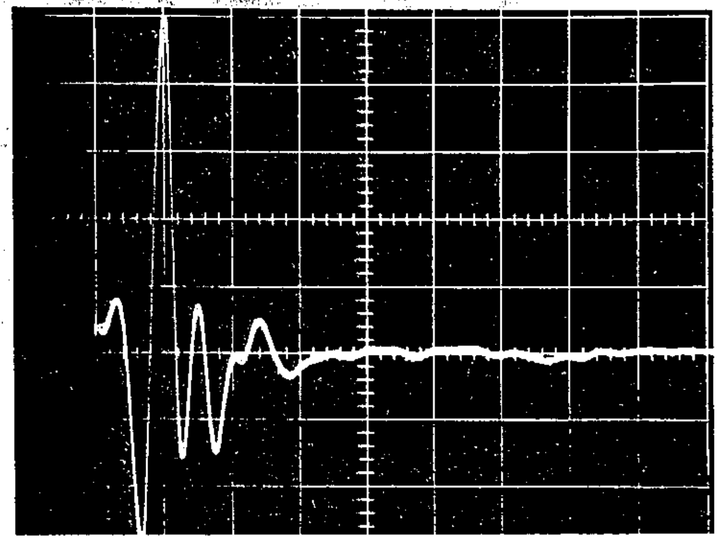


Figure 6 SIGNAL RETURN FROM FLAT PLATE AT DEPTH OF 2 inches

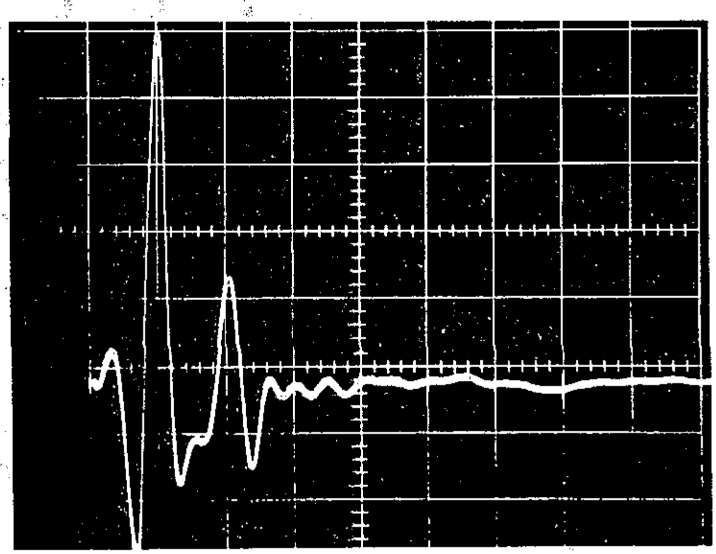


Figure 7 SIGNAL RETURN FROM FLAT PLATE AT DEPTH OF 4 inches

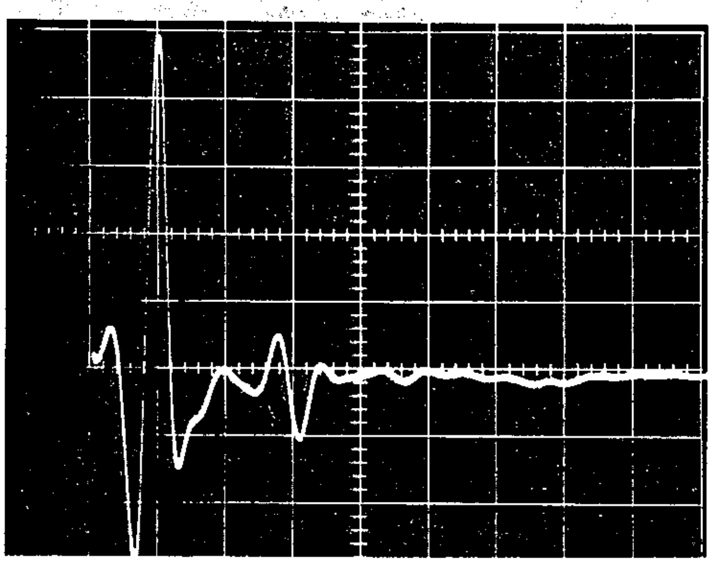


Figure 8 SIGNAL RETURN FROM FLAT PLATE AT DEPTH OF 6 inches

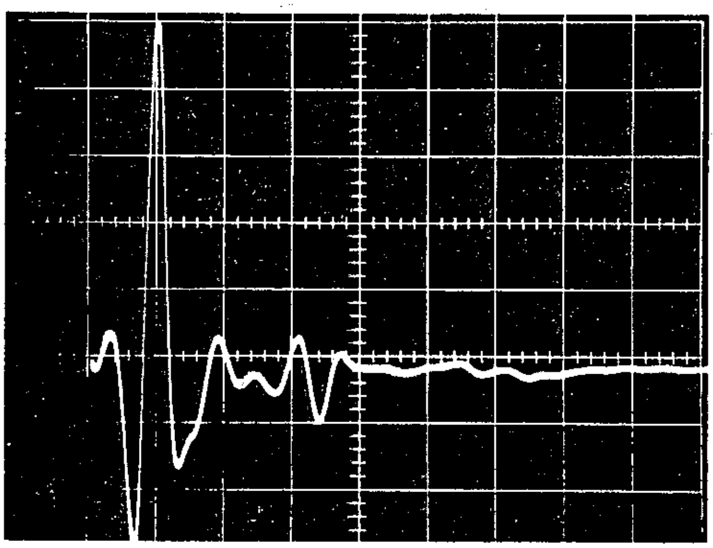


Figure 9 SIGNAL RETURN FROM FLAT PLATE AT DEPTH OF 8 inches

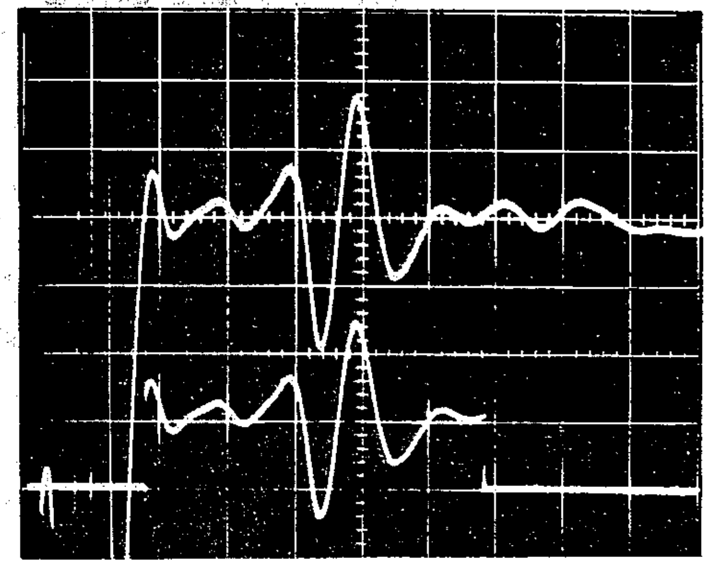


Figure 10 RADAR RETURN FROM STYROFOAM BLOCK 7 inches DEEP.

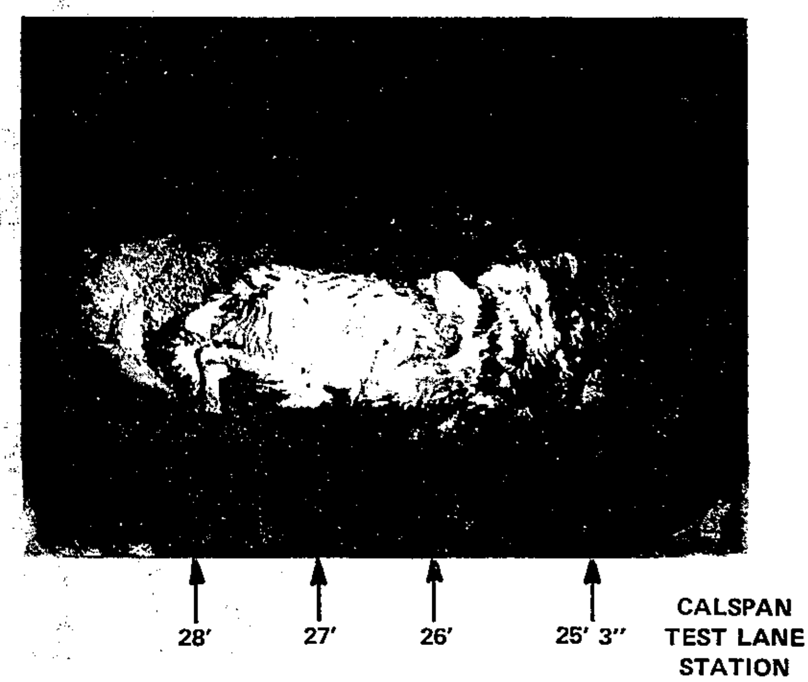
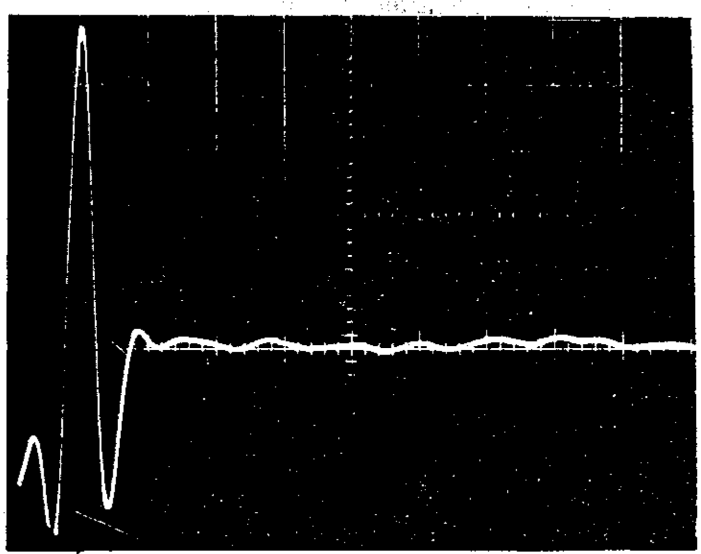


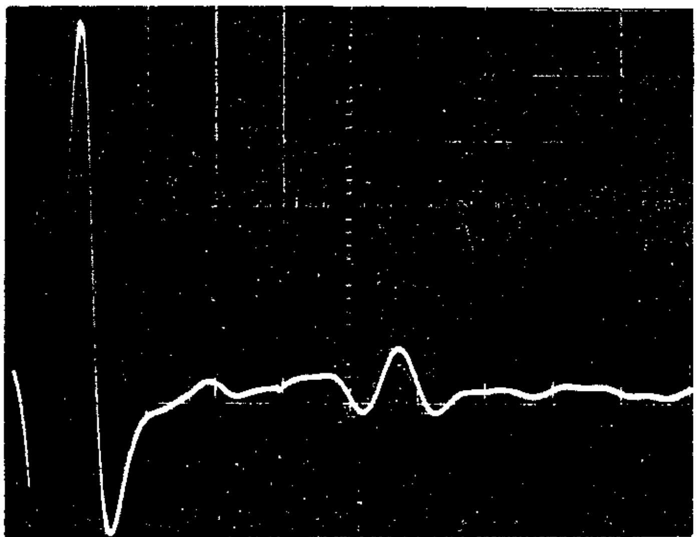
Figure 11 COLLIE DOG: 30″ LONG, 7″ THICK, WEIGHT 40 pounds. TO BE COVERED WITH 10″ OF SOIL. DOG DEAD ~4 hours.



VERTICAL SENSITIVITY: 100 mV/cm
HORIZONTAL SENSITIVITY: 1 ns/cm

SOIL SURFACE RETURN

Figure 12 SOIL SURFACE RADAR RETURN SIGNAL BEFORE BURYING DOG.



SENSITIVITY: 100 mV/cm
TIME: 1 ns/cm

SOIL SURFACE RETURN

RADAR RETURN AT 26'6" STATION: APPROXIMATE LOCATION OF CHEST CAVITY OF DOG'S BODY

Figure 13 RADAR RESPONSE OF A DOG'S BODY

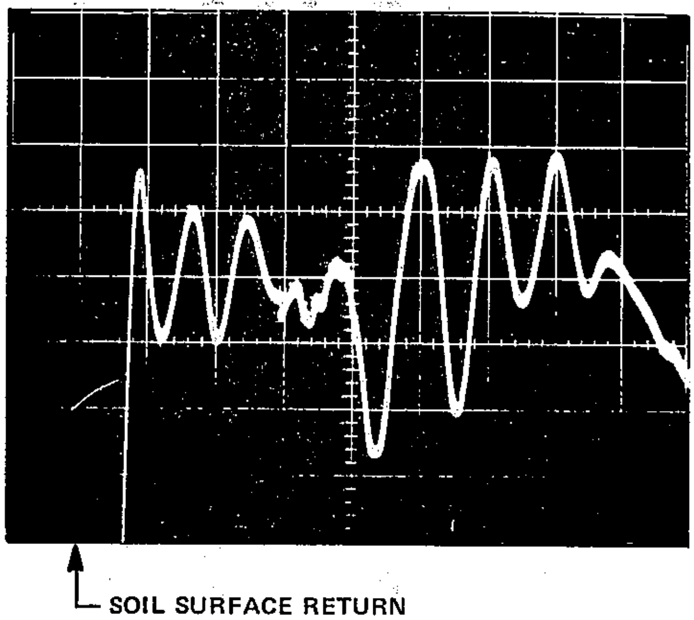


Figure 14 25′ 9″ STATION. EDGE OF HOLE: **DOG'S HEAD.**

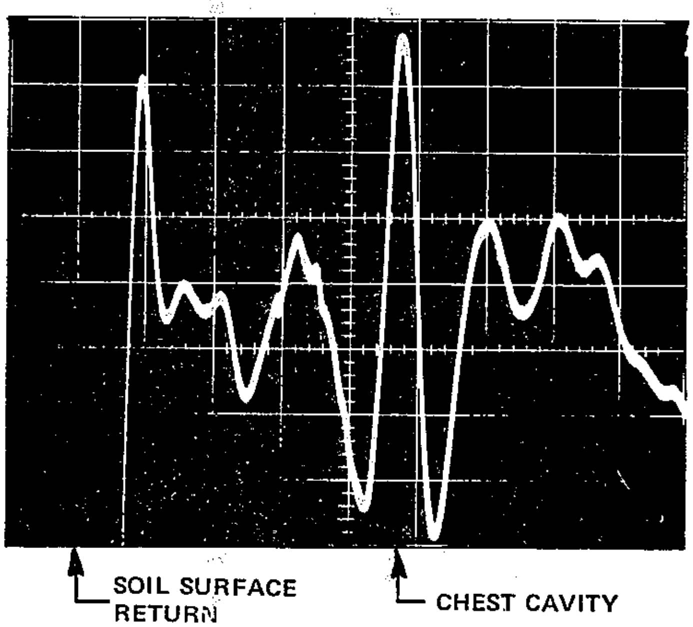


Figure 15 26′ 4″ STATION. **FRONT HALF OF DOG'S BODY.**

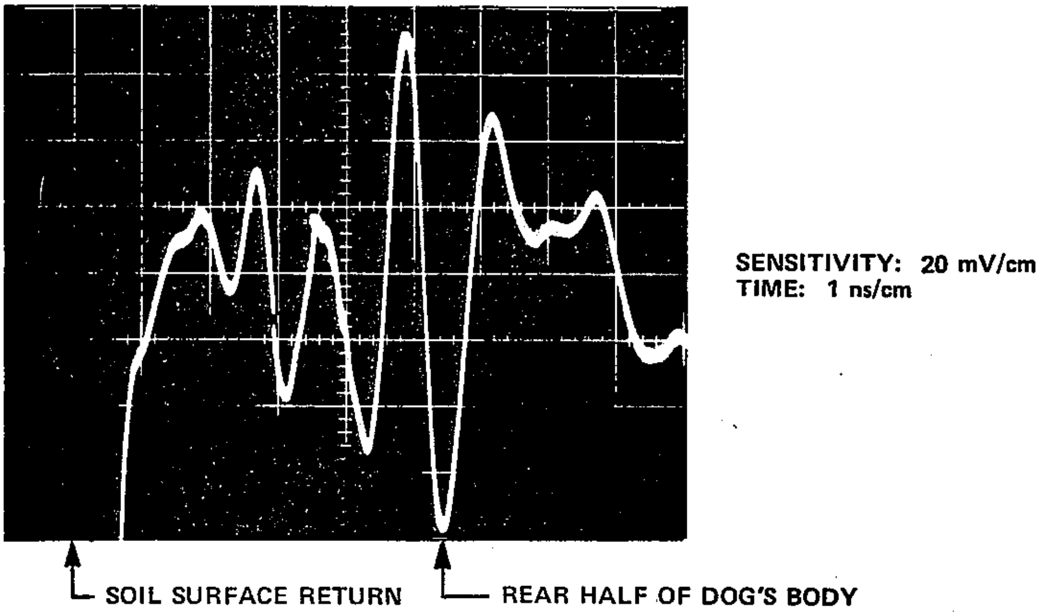


Figure 16 27' 6" STATION. REAR HALF OF DOG'S BODY.

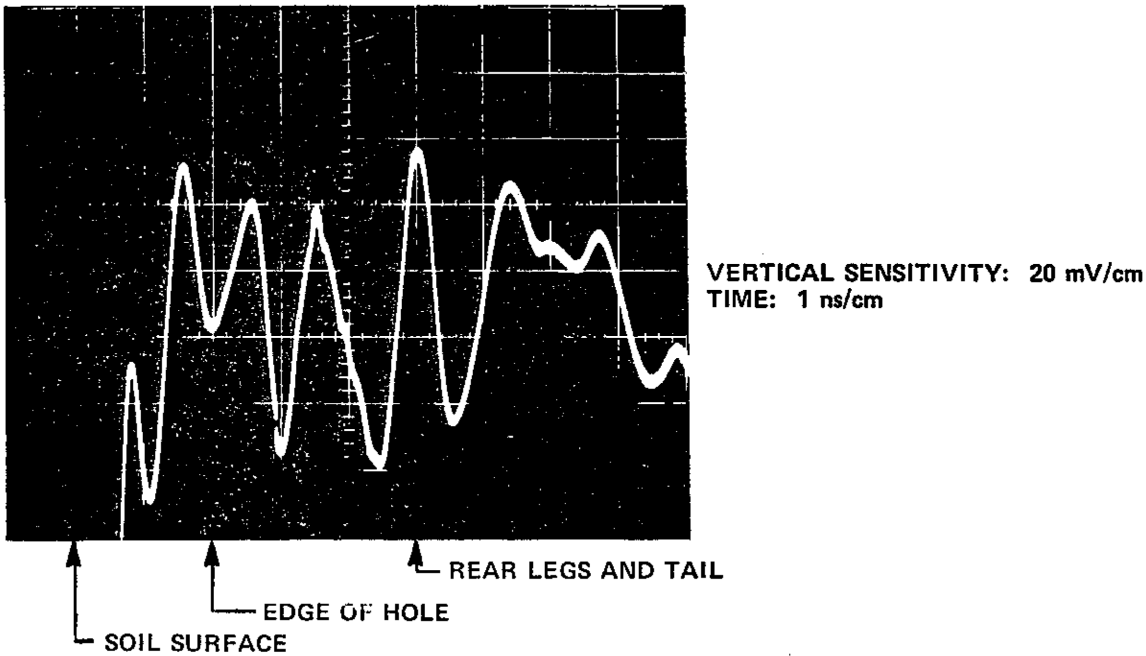


Figure 17 28' 3" STATION. DOG'S REAR LEGS AND TAIL.

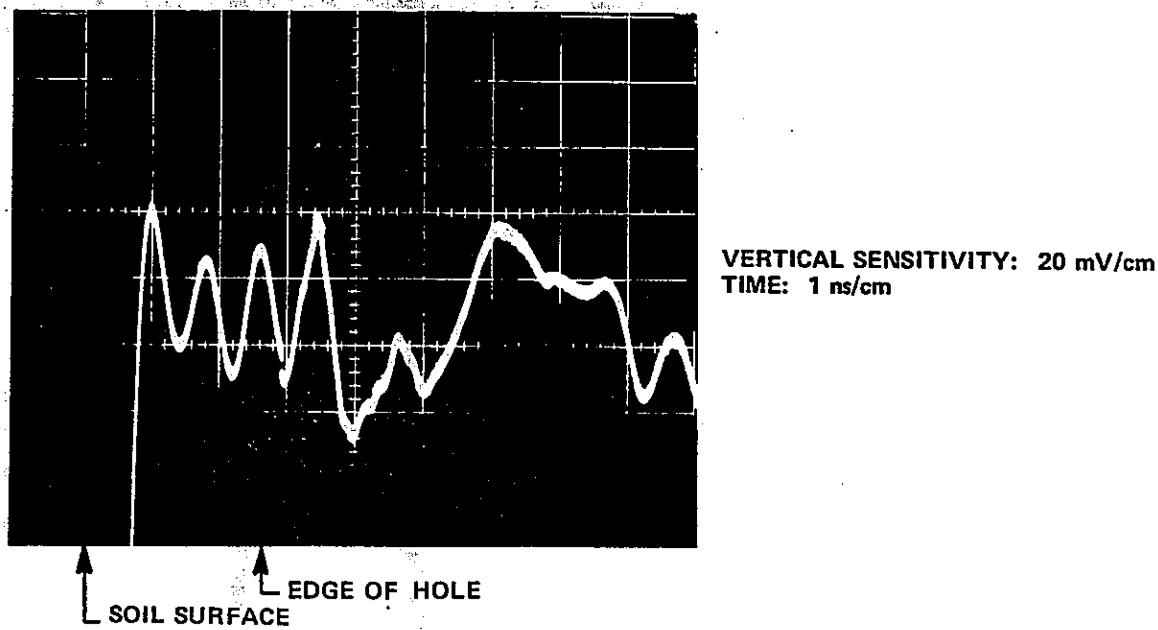


Figure 18 29' 3" STATION. PAST SUBJECT AT EDGE OF HOLE.

Table I
TIME DELAY vs PLATE DEPTH
(DRY CLAY: 4% MOISTURE CONTENT)

PLATE DEPTH (in)	MEASURED TIME DELAY (ns)	CALCULATED TIME DELAY (ns)
2	0.5	0.566
4	1.1	1.132
6	1.8	1.7
8	2.1	2.26

NEW YORK STATE THRUWAY AUTHORITY

Inter Office Memorandum

TO: Files

DATE: May 28, 1974

FROM: W. H. Clark, III, P. E.

SUBJECT: Calspan Corp. High Resolution Radar

Last year, Calspan utilized two Thruway bridge rehabilitation projects in the Buffalo area for testing the performance of their ground penetrating military radar on Portland Cement Pavements. This work was performed informally so far as the Thruway Authority is concerned. However, the pavement related tests were reported on in the "Highway Research News, Number 53, Winter 1973." Interpretation of this data was facilitated by an existing excavation through the pavement in question, which allowed physical measurements of thicknesses, reinforcing and voids while performing the tests. Other sources such as the "Calspan News" related to using the equipment to measure the extent of concrete deterioration in a bridge substructure element. Calspan did not record any data for this test and since deterioration was obvious, we can not vouch for the accuracy of the radar in this application.

On May 22, 1974 R. C. Donnaruma, F. J. Schork, M. M. Lastra (FHWA Region I Materials Engineer); and I met with Mr. Anthony V. Alongi of Calspan Corporation concerning the High Resolution Radar developed by Calspan for the Army. We had been receiving numerous inquiries about the device from State Highway Departments and private testing labs because of the HRB article, and in order to avoid further embarassment had invited ourselves to Calspan to be educated. Below is a summary of the device and my comments:

Calspan started research on this device in 1966 as an instrument to detect non-metalic anti-vehicle mines, (plastic or wood case, plastic pressure detonator, and plastic explosive). Mathematical modeling was used to determine the frequency and band width needed to detect such mines in soil. Considerable experimentation was required to eliminate false surface echos from the edges of the radar beam.

The radar unit scans on volume in normal solids 13' wide x 9" long to about 18" deep. Dry soils and materials such as asphalt concrete or portland cement concrete allow deeper penetration of the radar. It can resolve objects more than 6 inches apart and locate to ± 1/8 inch depth in homogeneous material - eg. it could be used to determine thickness of concrete pavement. Because of its short pulse (a 5 MH sine wave 10-9 sec period generated every 200 nano seconds) it is possible to have a very rapid scan (100 or 1000 scans per second) thus the potential of a pavement scan at normal traffic speeds, say 60 m.p.h. In addition, any number of units might be used to increase scan width. The Army demonstrator used 3 units for about a 40 inch scan. For engineering applications, output could be fed into a magnetic tape recorder and a computer used to plot and analyze the data.

Any change in dialectric constant (density, moisture, material, etc.) will cause an echo on the screen. The sharper the change the more sharp is the signature. Attached is a chart representing 100 ft. of a test strip with plastic targets buried in a gravel road (the soil surface echo is scaled out, besides the obvious targets note the variation in soil density in the road). The chart represents a scan 13" width by 18" deep from a moving vehicle.

In addition to the Army Mine Detection Division, Southwest Research Corporation presently has one finished unit under evaluation for soils testing. The unit we saw in operation was a "bread board" model. The Calspan Unit successfully located pipe (about 1½" diameter) 18 inches under a concrete pad, reinforcing in concrete below a 3" asphalt topping, and reinforcing in a concrete test slab. Besides locating reinforcing mat depth, it should be sensitive to delamination at the reinforcing level although this evaluation has not been attempted. It can detect voids under pavement and variation in subgrade moisture.

The device which emits about 1/10 the power of a police speed measurement radar does not require licensing as far as we know. In addition, it will not interfere with T V or radio reception.

Based on the demonstration and Mr. Alongi's explanation of the principles and performance aspects of the device, it appears to have considerable promise for rapid non-destructive testing. Below are some thoughts we had for uses which would justify the relatively high cost of the equipment:

1. Total pavement thickness measurement for concrete and asphalt concrete pavement (replace coring).
2. Checking depth of cover over reinforcing steel in bridge decks (replace the pacometer).
3. Condition survey of bridge decks under asphalt wearing course or monolithic decks for maintenance or prior to reconstruction.
4. Evaluation of subgrade drainage, below pavement.
5. Location of void areas or undermined areas under concrete pavement.
6. Soils investigations before, during and after construction.
7. Mud balls or other irregularities in concrete pavement

The only problem with the device is the identification of the subsurface material, you have to know what you are looking for. The application of this technology to the highway field will take a considerable amount of time and money.

CALSPAN is presently shopping for funding to continue development of this radar for Civilian applications. Interest has come from the Highway Field and Utility Companies (locating non-metalic pipe and conduit). Interestingly enough, Scotland Yard is quite interested in the device for locating buried cadavers (English murderers are generally quite neat.)

William H. Clark (mr)
Senior Civil Engineer
(Physical Research)

III:mr

cc: Mr. J. P. Pendleton
Attn: Mr. A. Gregory, w/attachment
Mr. Willet
Attn: Mr. Schork, w/attachment
Mr. Cleary
Attn: Mr. Donnaruma, w/attachment

Mr. Michael M. Lastra, Materials Engineer
Federal Highway Adminis$tration - Region 1
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Elsmere, New York 12054